INSTRUCTION MANUAL

POWER SUPPLIES UNLIMITED

QR LINE

NJE CORPORATION Kenilworth, New Jersey

INSTRUCTION MANUAL

FOR

QR-LINE

TRANSISTORIZED REGULATED

POWER SUPPLY

NJE CORPORATION
20 Boright Avenue
Kenilworth, N. J.
BRidge 2-6000

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SECTION I

SPECIFICATIONS AND DESCRIPTION

1-1. SPECIFICATIONS.

Input: 115 volts RMS ±10%, 60 cycles, ±5 cycles, single phase, approximately 4.5 amperes at 0.7 power factor at full load.

Output: Continuously adjustable by a front panel ten-turn potentiometer.

Model	Volts	Amperes	Resolution
QR-10-10	0-10	0-10	2 mv
QR-18-6	0-18	0-6	3 mv
QR-36-4	0-36	0-4	5 mv
QR-60-2.5	0-60	0-2.5	7 mv

Polarity: The output can be floated up to 500 volts peak above or below ground. Either polarity may be grounded to chassis.

Ripple: Total of hum and noise will not exceed 3 millivolts peak to peak.

Load Regulation:

Model	Static Load Regulation, No Load to Full Load	Dynamic Load Regulation, For a Full Load Step With a 0.5 microsecond rise time
QR-10-10	±0.01% or 0.5 mv*	600 mv
QR-18-6	±0.01% or 0.5 mv*	400 mv
QR-36-4	±0.005% or 0.5 mv*	200 mv
QR-60-2.5	±0.005% or 0.5 mv*	150 mv

*whichever is greater

Line Regulation: ±0.02% or ±0.5 mv, whichever is greater, for slow or step line changes of ±10%, at constant load.

Recovery Time: Less than 25 microseconds for a full load step.

Duty: Rated for continuous duty at ambient temperatures from 0°C to 50°C. Current rating must be reduced linearly to 0 at 85°C.

Termination: A barrier type terminal strip at the rear of the unit provides terminals for input, output, remote sensing, remote programming, dualling, and ground.

Series-Parallel (Dualling) Operation: Two or more units may be operated in series to provide higher voltages at rated current, or in parallel to provide higher currents at rated voltage.

Circuitry: Completely solid state. Silicon power rectifiers, silicon zener diode reference, germanium control and power transistors, all well-derated, characterize the quality and dependability of this supply.

Special Notes: This unit is convection-cooled. A high efficiency heat sink eliminates the need for blowers, increasing the reliability and life of the unit.

Stability: ±0.05% or ±2MV for 24-hour day and laboratory conditions.

TYPICAL TEST RESULTS QR-36-4			
STATIC LOAD REGULATION NL TO FL	OUTPUT 36V 1.6mv	15V .5mv	1V .8mv
STATIC LINE REGULATION NL LL TO HL	6mv	3mv	.4mv
STATIC LINE REGULATION FL LL TO HL	8mv	4mv	.4mv
RIPPLE:	MAX. 1.2mv P.P.		
LOAD DYNAMIC:	INPUT: 115V OUTPUT: 36V	CURRENT:	0-4A +150mv 4A-0 -150mv
LINE DYNAMIC:	105V - 115V - 105V ±2mv 115V - 125V - 115V ±2mv		
MAX. SHORT CIRCUIT CURRENT:			7A
MAX. SHORT CIRCUIT SERIES TRANSISTOR STORAGE:			3V

Protection: Load and power supply protection for momentary overload or short circuit conditions is accomplished by an electronic current limiting circuit.

If the fault condition is sustained, automatic removal of the load is effected by the thermal characteristics of a slow-blow type fuse.

Remote Sensing: Sensing terminals, separate from the output terminals, are provided in order that the unit may "sense", and regulate against, the voltage at the load rather than the voltage at the output terminals.

Remote Programming: This circuit has a sensitivity of about 140 ohms per volts. "Remote Program" terminals are provided. By varying the remote resistance in series with these two terminals, the output voltage may be accurately controlled from zero to rated voltage.

Meters: Two 2-1/2" rectangular 2% meters are furnished installed on the front panel.

Model	Ammeter Range	Voltmeter Range
QR-10-10	0-10	0-10
QR-18-6	0-10	0-20
QR-36-4	0-5	0-50
QR-60-2.5	0-5	0-80

Dimensions: 3-1/2" high, 19" wide, 16-5/8" deep.

Weight, net: 40 pounds.

Weight, shipping: 45 pounds.

Mounting: Suitable for laboratory bench use, or for 19" rack mounting.

Finish: Panel finish is two-tone gray enamel.

Panel Elements:
"On-off" switch
AC line fuse in extractor post
"On" pilot light (red)
Output voltage control knob
Output voltmeter
Output ammeter

Environmental Conditions: This power supply will operate satisfactorily over the entire temperature range from +50° F to +120° F, with humidity up to 90% at altitudes up to 10,000 feet, without derating.

1-2. The power supply chassis assembly has an over-all width of 17 inches, and is mounted on a standard 19-inch relay rack panel. Components are mounted on sub-chassis which are secured between two side frames. This construction permits a free flow of air among the components in a vertical direction, to facilitate dissipation of heat by convection as well as radiation.

1-3. The unit is designed for installation in a standard relay rack or cabinet as well as for use as a bench instrument. It is equipped with a perforated metal cover which serves to protect both equipment and user during operation. All input, output, and control connections are available on a barrier-type terminal strip at the rear of the unit, and include two chassis ground connections, and the following terminals:

1. AC input
2. AC input
3. Remote control
4. Remote control
5. Dualling
6. Dualling
7. Positive sensing
8. Positive output
9. Positive capacitor
10. Negative capacitor
11. Negative output
12. Negative sensing

1-4. The front panel elements consist of rectangular output voltmeter and ammeter of 2% accuracy, an AC on-off switch, output voltage adjust, a red pilot lamp to indicate application of AC input power, and AC input fuse. The DC output circuit fuse is mounted on the rear of the chassis alongside the terminal strip.

SECTION II

INSTALLATION AND OPERATION

2-1. UNPACKING. The power supply is shipped in a cardboard carton which is floated on sufficient insulation in a heavy-duty shipping carton. Aside from normal precaution against damage to the unit in opening the cartons and removing the unit, no special procedures are required. The literature packed with the supply should be removed and held for reference in operating the equipment.

2-2. INSTALLATION. The supply can be mounted in any convenient location for bench use, and requires no adjustment or modification for such application. If the unit is to be installed in a housing, it is recommended that the rack or cabinet used be equipped with angle brackets, shelves, or slides to receive the unit, rather than suspending the assembly by its front panel mounting screws. The panel is notched for standard rack mounting.

2-3. When the unit has been properly placed in position, or mounted in its rack and secured in place by the panel screws, make the following connections:

1. Using no. 16AWG wire, connect either the positive (TB1-8) or negative (TB1-11) DC output terminal of the supply (depending upon desired output polarity) directly to the chassis ground terminal at the barrier strip on the rear of the chassis, and connect the ground terminal to the system ground. If it is necessary that the power supply circuit float above or below ground, the output terminal should be connected to the chassis ground terminal by a 0.1 microfarad 600 W VDC capacitor in place of the direct connection. Use of this by-pass capacitor will improve the stability of the circuit in the ungrounded condition, and reduce the effect of external interference and hum.

2. Connect the positive and negative output terminals, TB1-8 and TB1-9, respectively, to the corresponding terminals of the external load, using no. 10 AWG wire.

3. Connect the positive sensing terminal TB1-7 to the positive terminal of the remote load, and the negative sensing terminal TB1-12 to the negative terminal of the remote load. A twisted pair of no. 20 AWG (or larger) wire should be used for these connections. If accurate regulation at the remote load is not essential, then the sensing leads may be connected directly at the power supply output terminals; i.e. jumper TB1-7 and TB1-8, and jumper TB1-11 and TB1-12.

4. Output Capacitor Connections. The power supply has been shipped from the factory with the POS CAP terminal TB1-9 jumpered to POS OUT terminal TB1-8 and with

NEG CAP terminal TB1-10 jumpered to NEG OUT terminal TB1-11. This connection is satisfactory for most applications. However, if improved transient and dynamic characteristics are required, the POS CAP and NEG CAP terminals should be connected to the remote load on separate, heavy-duty leads. Further improvement can be effected by using an independent capacitor (available from the factory) mounted physically as close to the ultimate load as is practical. Consult the NJE Engineering Department on special transient problems.

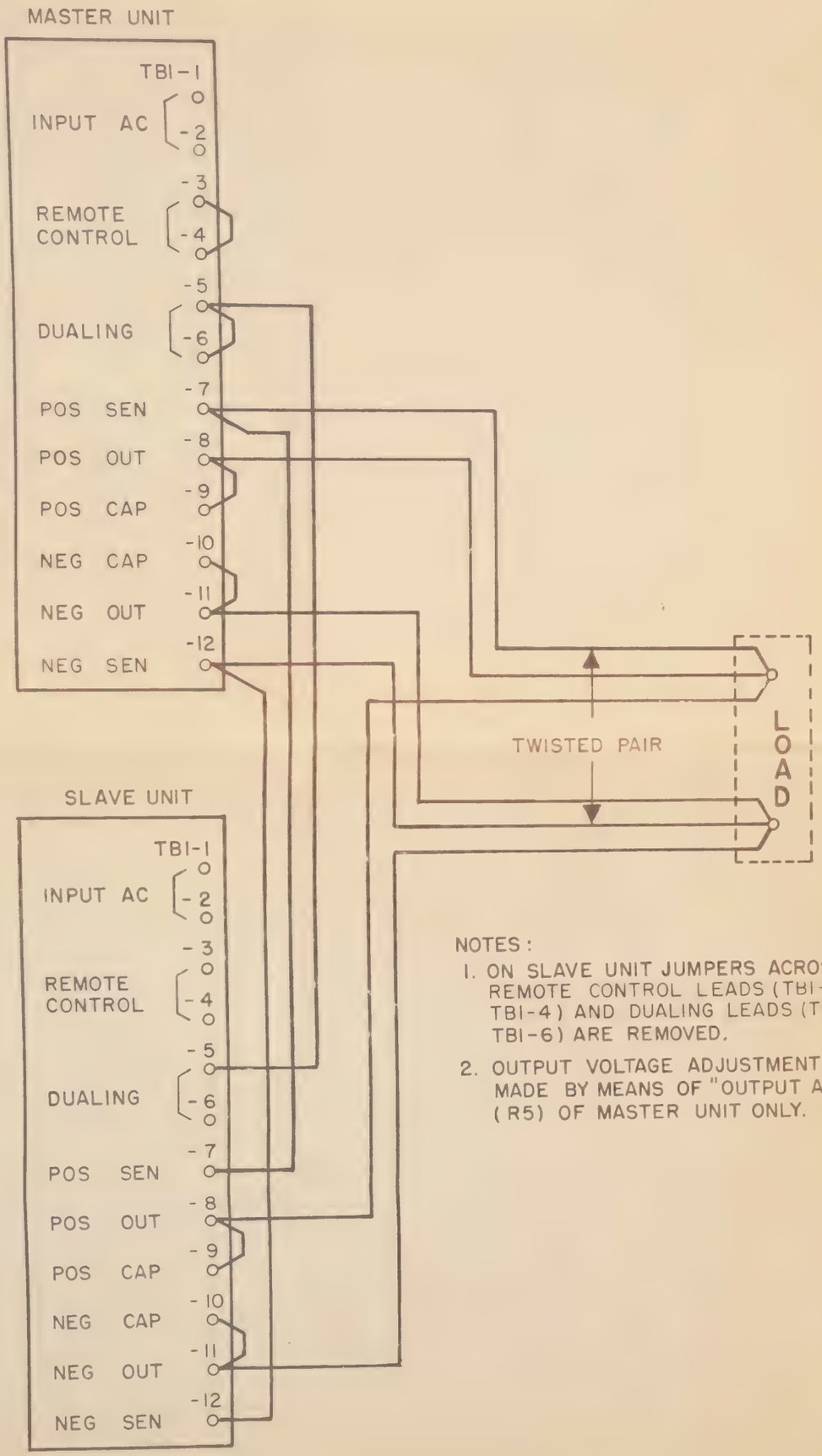
5. Remote Control - Programming. Terminals TB1-3 and TB1-4 are provided for the insertion in series of a remote control programming resistor. This circuit has a sensitivity of about 140 ohms per volt. When the panel voltage adjustment is set to zero, the output voltage may be accurately controlled from zero to rated voltage by varying the remote resistance.

6. Dualling. Two supplies may be operated in parallel (with an overall current derating of 10%), or in series. Consult the Dualling Schematic (Figure 1) for proper interconnection and wiring of the individual supplies and the load.

7. Connect the deactivated input line (115 volts nominal, 60 cycles, single phase) to the AC input terminals TB1-1 and TB1-2 on the barrier strip, using no. 14 AWG wire.

2-4. OPERATION. Set the AC control switch in OFF (open) position and energize the AC input line. Set the OUTPUT ADJUST control to full counterclockwise position, then place the AC control switch in the ON position. The indicator on the front panel should light. Observing the panel voltmeter, adjust the load voltage to the desired value, by means of the OUTPUT ADJUST. Check the load current meter to avoid overload conditions. If the required voltage value cannot be achieved, deenergize the input line and check connections on the rear terminal strip before referring to the troubleshooting section of this manual.

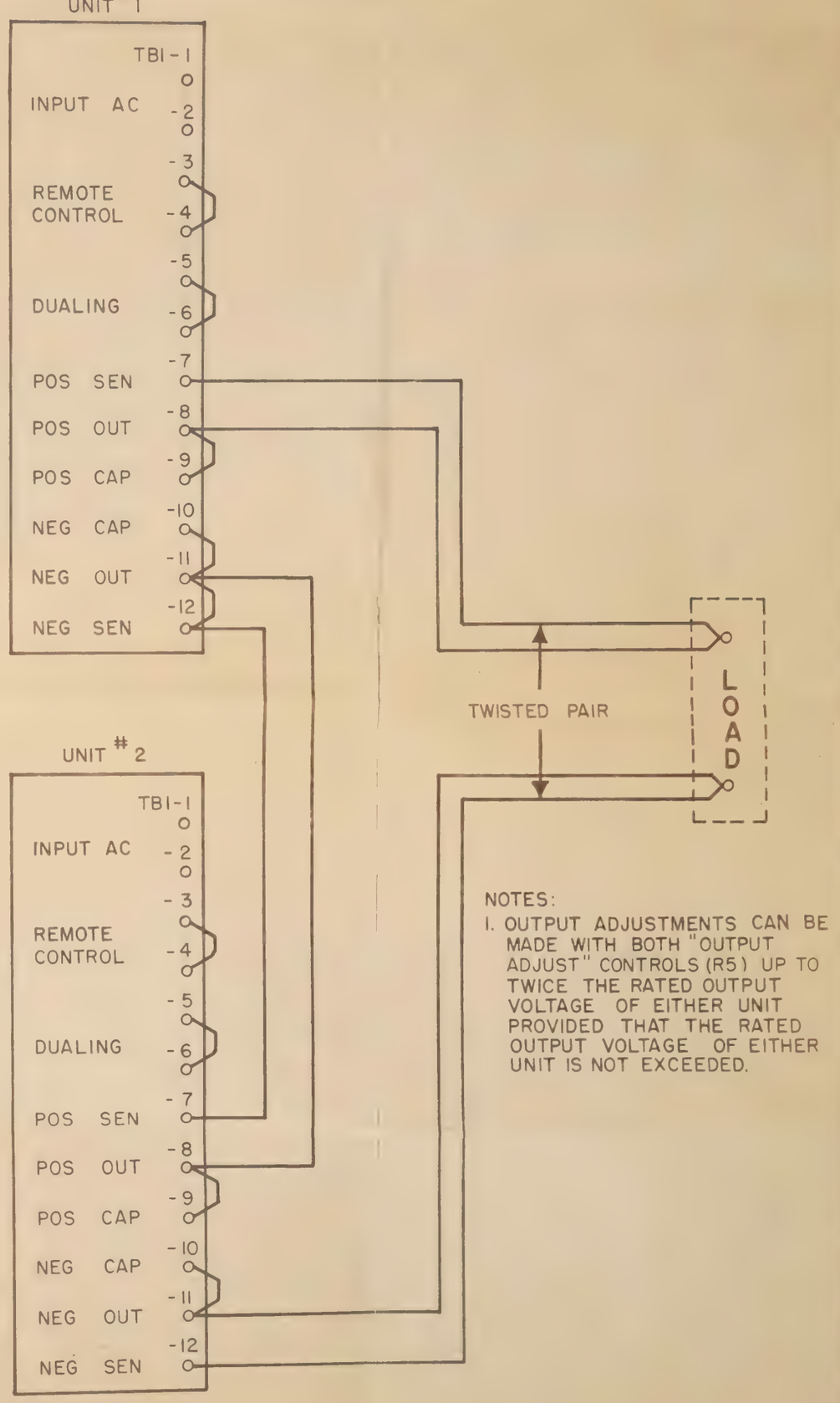
DUALLING SCHEMATIC
FIGURE 1



NOTES:

1. ON SLAVE UNIT JUMPERS ACROSS REMOTE CONTROL LEADS (TBI-3 & TBI-4) AND DUALING LEADS (TBI-5 & TBI-6) ARE REMOVED.
2. OUTPUT VOLTAGE ADJUSTMENT IS MADE BY MEANS OF "OUTPUT ADJUST" (R5) OF MASTER UNIT ONLY.

PARALLEL CONNECTION



NOTES:

1. OUTPUT ADJUSTMENTS CAN BE MADE WITH BOTH "OUTPUT ADJUST" CONTROLS (R5) UP TO TWICE THE RATED OUTPUT VOLTAGE OF EITHER UNIT PROVIDED THAT THE RATED OUTPUT VOLTAGE OF EITHER UNIT IS NOT EXCEEDED.

SERIES CONNECTION

SECTION III

PRINCIPLES OF OPERATION

3-1. GENERAL. A simplified block diagram, illustrating the basic elements of the circuit and the signal flow, is shown in Figure 2. The AC line voltage is converted to a practical value by the power transformer and after passing through the magnetic storage regulator, is rectified by a full-wave diode rectifier. A capacitor-input filter smooths the pulsating DC output of the rectifier, providing a low-ripple, unregulated DC voltage to the output series regulator. The output voltage furnished to the load by the series regulator is monitored by a feedback amplifier which compares this voltage with a stabilized reference voltage and amplifies the difference between the two voltages. The output of the amplifier is used to control the regulator in such a way that it counteracts any change in the DC output voltage, thereby furnishing an essentially constant voltage to the external load. The magnetic storage regulator is basically a magnetic amplifier which controls the magnitude of average DC voltage at the capacitor input filter in such a way as to maintain the storage voltage across the series regulator within its dissipation capability.

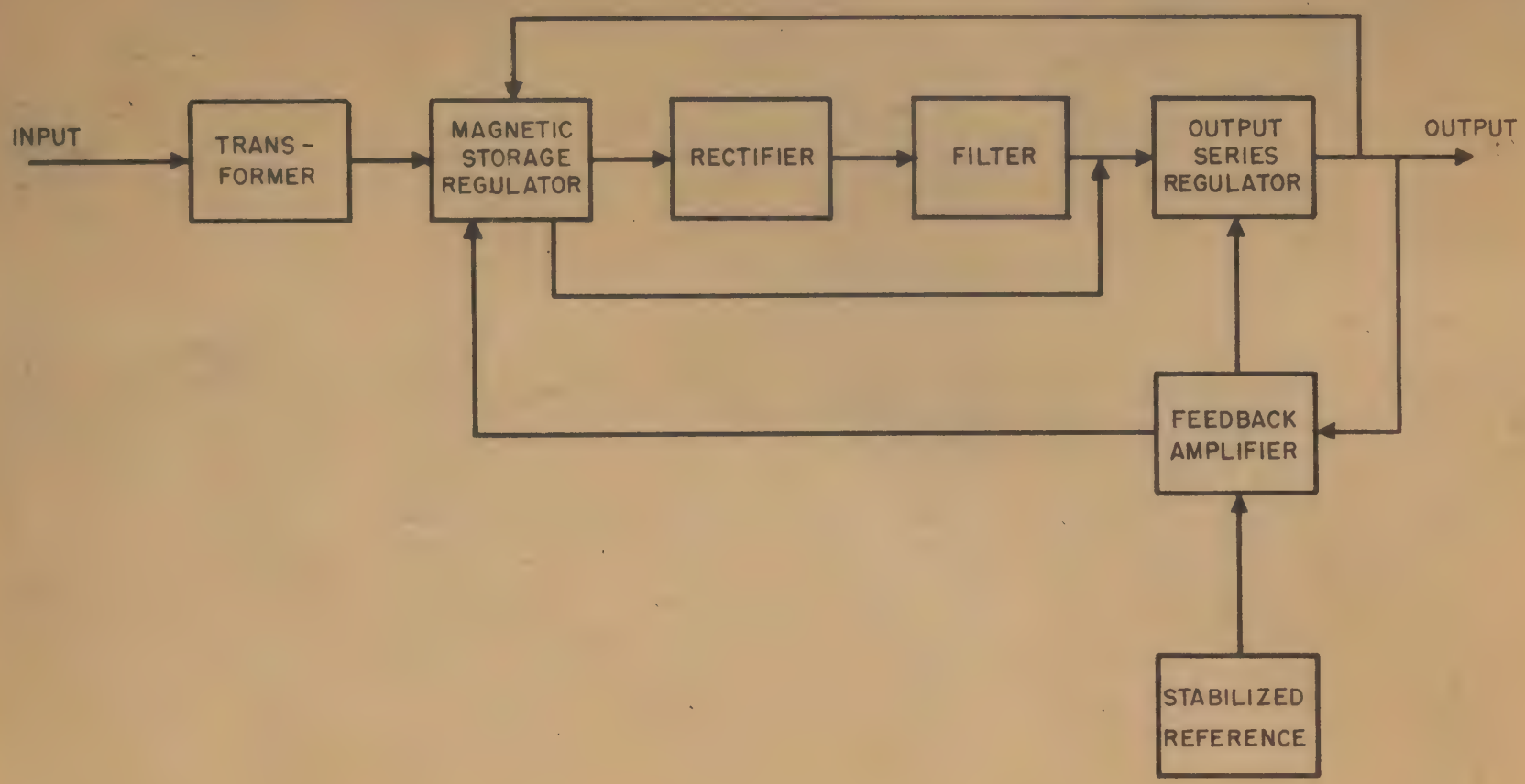
3-2. DETAILED CIRCUIT DESCRIPTION. Circuit references in the following material apply to the schematic diagram at the back of the manual. This diagram shows electrical relationships, without regard to actual physical location of the components, and is laid out in an arrangement approximately the same as that in the Block Diagram, Figure 2.

3-3. The power supply is energized by connecting 115 volts (nominal), 60 cycles*, single-phase, to the input terminals, and closing switch (S1), attested by the lighting of pilot lamp (DS1).

3-4. The power transformer (T1) converts the 115VAC input line to an appropriate value on its secondary winding for operation of the magnetic storage regulator (SL1 and SL2). The magnetic storage regulator output voltage is rectified by a full wave rectifier (CR1 and CR2), providing a pulsating DC output which is smoothed by the capacitor input filter (C1) and applied through a regulating transistor assembly (Q1 thru Q3) to the external load. Capacitor (C2) provides additional filtering of the output, and reduces the internal impedance of the supply for high-frequency load variations.

3-5. The output voltage on the auxiliary winding of transformer (T1) is rectified by diodes (CR-101 and CR-102) and (CR-103 and CR-104), and filtered by capacitor input filter (C102) - (C103) to provide positive and negative operating potentials for the feedback amplifier. Zener diode (CR109) in conjunction with its load resistor (R110) provides regulated +18 volts DC, while diode (CR110) with resistor (R108) provides -18 volts DC (measured with respect to the neutral bus, terminal (13) of the amplifier). These zener diodes function in a manner analogous to that of a gaseous voltage regulator tube, providing a relatively constant output

*400 cycles, for units equipped with a 400-cycle magnetic storage regulator.



SIMPLIFIED BLOCK DIAGRAM

FIGURE 2

voltage across their terminals despite variations in the conducted current. Output voltage from diodes CR-101 thru CR-104 also provide current for the magnetic storage regulator SL1, SL2 control windings, and regulator transistors (Q1 thru Q3) I_{co} drain.

3-6. The feedback amplifier consists of three stages of amplification, the first two of which are balanced amplifiers, assuring minimum sensitivity to fluctuations in ambient temperature or operating voltages. The input signal for the amplifier is derived from a sensing voltage divider connected across the output of the supply. This divider consists of resistors R120 and R121 in the amplifier, and resistor R5 on the main chassis. The resistance setting of R5 determines the operating value of the DC output voltage of the supply in a manner which will be explained below. Resistor R5 is the output voltage control knob on the front panel. F101 at the base of Q108 provides protection for both the precision feedback resistor R5 as well as the transistor during surges arising because of transient load conditions.

3-7. The negative end of the sensing voltage divider (negative end of resistor (R120)) is returned to the negative output of the supply through zener diode (CR111) and the negative sensing lead. The diode, in conjunction with its load resistor (R119) provides a highly stable potential of 6 volts DC for use as a comparison voltage by the input stage (Q107, Q108) of the feedback amplifier. When the output of the power supply (measured at the load) is precisely at its selected nominal value, the voltage at the base of transistor (Q108) (derived from the sensing voltage divider at terminal 20) is at the same level as the base of transistor (Q107), and the input stage is in balance. Under this condition, any tendency of the load voltage to vary in either direction will unbalance the amplifier, resulting in corrective action which compensates for the impending change, and holds the load voltage at its established value, as explained below.

3-8. Transistors (Q107) and (Q108) are PNP type units, operated in common-emitter mode, and connected as a balanced differential amplifier. Their outputs, taken across load resistors (R-117) and R-118) are direct-coupled to the bases of the succeeding differential amplifier stage (Q-105) - (Q-106), which consists of two NPN transistors operated in common-emitter mode. The output of (Q-105), from its load resistor (R-114), drives the base of the single-ended output stage (Q-104). The output of the amplifier is tied directly to the base of the driver transistor (Q-101).

3-9. Regulation of the DC output is performed by a double regulating system. A transistor series regulator consisting of power transistors Q1, Q2, and Q3 operating in parallel provides high speed regulating action to correct for ripple and transient variations, both at its input, C1, and at the output of the supply. The amplifier loop which provides correction signals to the series regulator is driven directly from the output through the feedback resistor divider and is comprised of transistors Q108, 107, 106, 105, 104 and driver transistor Q101. A magnetic amplifier consisting of SL1 and SL2 whose control windings are driven by a transistor pair Q102 and Q103, is designed to regulated the storage voltage across the series regulator. The circuitry is such that regardless of the output load requirement, the power dissipation of the series transistor regulator is maintained within its ratings.

3-10. The sequence of corrective action for the magnetic storage regulator is as follows: The input to transistor Q102 is the zero level and is connected to one end of the series regulator, i. e., the negative output terminal. The voltage at the common collector terminals of Q1, Q2, and Q3, the other end of the series regulator, is sensed by the three-resistor divider network R105, R104 and R111 with respect to the +18 volt zener level at cathode (top) end of CR109. This divider is sensitive to both the voltage across the series regulator as well as the current through it and by feedback amplifier action, tends to null the voltage at Q103 base with respect to the zero level at Q102 base. The common emitter of this stage is fed from the positive bias supply at C102 through resistor R3. The collectors drive the control windings of the magamp, and R4 is a current limiter for the control windings fed from the negative bias voltage at C103. The feedback is negative, so that if for some reason the voltage across the series regulator tends to increase (due to an increase in line voltage, for example), a negative-going signal is applied to the base of Q103, producing a current change in the magnetic amplifier control windings in a direction which tends to restore the series regulator to its original voltage condition. Similar correction occurs for a decreasing series regulator voltage.

Output voltage control is achieved in the following manner. Suppose the Output Adjust R5 is varied to produce a reduced output voltage. Since the series regulator response is much faster than the magnetic amplifier storage regulator, a momentary situation develops in which the series regulator voltage increases, i. e., the voltage at C1 holds momentarily while the output voltage is reduced. As described above, when the series regulator voltage increases, the storage regulator amplifier loop causes the magamp output to restore the original series regulator voltage. In this case, the voltage at C1 drops to compensate for the output voltage reduction. It is thus seen that the magamp output at C1 tends to "track" the output voltage, and in this manner maintains the series regulator dissipation within fixed limits. Other components associated with the storage regulator are the following:

R1: A bleeder required to maintain a minimum current in the magamp gates.

C101 and R106: Stabilization against oscillations in the magamp feedback loop.

R109: Low impedance bypass for the control windings.

3-11. The sequence of corrective action around the series-regulator feedback loop is as follows: The input to transistor (Q-107) is the zero reference level -- in this case the voltage at the negative terminal of the load. The input to transistor (Q-108) is the difference between the voltage across diode (CR-111) (the reference voltage) and the voltage on the sensing voltage divider at terminal (20). When the DC load voltage is at the selected value, the voltage at the divider and the voltage across diode (CR-111) are equal, though of opposite polarity, and cancel each other out, so that the base of Q-108 is at the same potential as the base of (Q-107) and the outputs of the two transistors are balanced. When the load voltage tends to deviate from the selected value in either direction, due to a change in the load current or in input line voltage, this causes the voltage on the sensing divider to differ from the voltage

across the reference diode (CR-111) and the difference (or "error") voltage unbalances the amplifier stage (Q-107) - (Q-108). This difference appears in amplified form in the output of this stage, and is further amplified by the subsequent amplifier stages before being applied to the driver transistor (Q-101). The output of the driver transistor causes the regulating transistors (Q1 through Q3) to increase or decrease its conductivity in accordance with the error signal so that its overall emitter-collector voltage drop absorbs the impending variation in load voltage, maintaining an essentially constant value of voltage across the load terminals. Capacitor (C104) assists the amplifier in responding to rapid changes in load voltage by bypassing a portion of the sensing circuit. The more rapid the change, the greater is the initial transfer of voltage direct to the input of the amplifier, enabling it to anticipate any radical load variation before the excursion becomes significant.

3-12. The sensitivity and speed of response of the corrective feedback circuit is such that the above-described action occurs almost instantaneously, and the actual excursion of the load voltage is held to a very small value. The circuit is a true proportional regulator, and must allow a small but finite "error" to exist between the required and actual regulated voltage, so that this error, however small, can generate the correction signal. By proper circuit design, the error is held to a value which remains within the specified regulation allowance of the power supply.

3-13. When resistor (R5) is readjusted to produce a different value of output voltage, the circuit makes a correction similar to that described above. Altering the resistance in the sensing voltage divider unbalances the input stage of the feedback amplifier, which then causes the circuit to produce a new value of voltage such that the drop across resistors (R120) - (R121) again equals the drop across diode (CR111). Reducing the value of resistor (R5) for example, momentarily increases the drop across (R120) (R121) (assuming a constant value of output voltage). However, this unbalanced condition at the amplifier input causes the DC output voltage to decrease until the drop across (R120) - (R121) again equals the drop across (CR111) and the circuit stabilizes at this new operating point, establishing a lower value of DC output voltage. See description of corresponding storage regulator action in paragraph 3-10.

3-14. Resistor (R120) in the amplifier is provided to permit compensating for manufacturing tolerances in diode (CR111), its load resistor (R119), and resistor (R121). (This resistor is adjusted at the factory and locked.) If any of these components are replaced, check to see that full rated output voltage of the supply is obtainable at full load, with the voltage control at maximum clockwise position, with line voltage of 105 volts. If not, readjust (R120) to provide full voltage under these conditions.

3-15. Overload current limiting action is provided by diodes CR105, 106, 107, and 108. These produce a forward voltage drop of approxi-

mately 2.5 volts and effectively clamp the driver transistor base, Q101, when the current reaches approximately 150% of maximum. When the base is clamped, the series regulator voltage begins to increase as the load resistance is further reduced. Increased series regulator voltage causes the magnetic storage regulator to react to drive the output voltage down. Thus, at a given voltage, if the load resistance is gradually reduced, the output voltage will regulate to rated load. As the resistance continues to decrease, the load will increase to about 150%. At this condition, the output voltage will begin to fall off until short circuit is reached.

3-16. R2 is a bleeder to provide minimum current for the series regulator at no load. R107 provides a path for the series regulator leakage current at no load (I_{co}).

SECTION IV

MAINTENANCE

4-1. GENERAL. This section is arranged in the form of a trouble-shooting chart, with symptoms listed approximately in accordance with the frequency of occurrance. Possible causes for each, and their remedies, are listed in logical succession beginning with the most common, to facilitate rapid location and isolation of a defective element.

4-2. SPARE MODULES. Where practical, it is recommended that one or more spare printed circuit boards and regulator assemblies be kept available for use in maintenance. This will reduce down-time to a minimum, and permit easy testing by direct substitution, making it possible to repair a defective module at some convenient time and avoid prolonged interruption of operation.

4-3. MALFUNCTIONS. The various ways in which DC power supply can deviate from normal operation are listed below. Each condition is treated separately in the charts that follow. Component symbol designations refer to the schematic diagram at the rear of the manual. Parts locations are indicated in the parts layout photograph also included at the rear.

MALFUNCTION	TYPICAL MAGNITUDE
1. No output voltage at any control setting.	Zero or negative DC output voltage.
2. Low output voltage.	Maximum output voltage obtainable at no load is less than maximum rating.
3. High output voltage.	Minimum output voltage obtainable at no load is more than maximum rating.
4. Failure to regulate.	Output voltage drops 5% or more when load is applied, or varies ± 2% or more under a ± 10% variation in line voltage.
5. Poor regulation.	Regulation better than above, but not within specification.
6. Excessive ripple.	
A. With good regulation.	RMS ripple exceeds specification, but regulation is within specification.
B. With poor regulation.	RMS ripple exceeds specification, and regulation exceeds specification.
7. Instability.	
A. Random large excursions.	Output voltage "hops" intermittently by 5% or more, with constant load, and constant line voltage.

MALFUNCTION	TYPICAL MAGNITUDE
7. Instability. (continued)	
B. Gradual drift in one direction.	Output voltage changes by 1% or more per minute, after 15-minute warmup.
C. Excessive drift under heavy load only.	Output voltage changes by 1% or more per minute after a 15-minute warmup, but only after application of a heavy load.
8. Inadequate transient suppression.	Failure to "zero-lag". Upon sudden application of a full load increase, output voltage dips sufficiently to cause a visible momentary deflection of the voltmeter needle.
9. Oscillation.	
A. High frequency.	Under constant load, output voltage is modulated by sawtooth or sine-wave with frequency of 200 cycles or more per second.
B. Low frequency.	At constant load, output voltage exhibits relaxation modulation at or below 200 cycles per second.

4-4. NO OUTPUT VOLTAGE AT ANY CONTROL SETTING.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Pilot light (DS1) not lit.	1. No line power, or defective input connection.	1. Check power source, lines and connections.
	2. Input fuse (F1) blown.	2. Replace fuse. If fuse blows repeatedly, do not overfuse.
B. Repeated blowing of fuse (F1).	1. Shorted rectifiers (CR1 and/or CR2).	1. Replace.
	2. Shorted capacitors (C3 and/or C4).	2. Replace.
C. Pilot light (DS1) lit.	1. Output fuse (F2) blown.	1. Replace fuse but do not overfuse.
D. Output fuse (F2) blows repeatedly, pilot light (DS1) lit.	1. Dead short on output circuit.	1. Clear short or short in external wiring and/or circuitry.
	a. External	a. Check for overload.
	b. Internal	b. Shorted filter capacitor (C1 or C2) or wiring short.

SYMPTOM	POSSIBLE CAUSE	REMEDY
E. Unregulated DC across (C1) zero or low. Fuses (F1 and F2) not blown.	1. Open rectifiers (CR1 and/or CR2).	1. Replace rectifier or rectifiers.
	2. Open gate windings on (SL1 and/or SL2).	2. Replace (SL1 and/or SL2).
	3. Primary or secondary power transformer (T1) open.	3. Replace transformer (T1).
	4. Magamp circuit controls to zero. This can occur only at heavy loads.	4. Look for cause of load. If it is external, remove, and observe if voltage is affected. When overload condition is corrected and low voltage at (C1) persists, change transistors (Q102 and Q103).
F. Unregulated DC present at (C1), but more than 15-25% higher than DC output.	1. Entire, or major part of unregulated DC voltage across (C1) absorbed by regulator transistors (Q1 through Q3). Caused by short or excessive leakage between base of driver or regulator transistors (Q101 or Q1, 2, 3), respectively, and any positive voltage or ground. (For example: If positive output is operated at chassis ground and a wiring short or excessive leakage exists between base of (Q101) and chassis.)	1. Inspect for short. Isolate driver transistor from heat sink and chassis, and operate unit for brief interval. If this restores normal operation, replace driver insulation, and/or driver itself, as necessary. If not cleared, repeat for regulators Q1, Q2 and Q3.
	2. Amplifier or sensing circuit defective.	2. Check by momentarily shorting base to collector of (Q101). If DC output is restored, amplifier or sensing circuit is at fault. See end of this Section for amplifier check.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	3. Rate sensing capacitor (C104) shorted internally, or by external wiring short.	3. Inspect for short. Disconnect one terminal of capacitor. If DC output is restored, replace capacitor.
	4. Defective driver transistor.	4. Check by momentarily shorting base to collector on driver transistor at no load. Replace driver transistor.
	5. Ammeter (M1) open.	5. Check by momentarily shorting meter terminals. Replace.
	6. (R101 through R103) all open.	6. Replace.

4-5. LOW OUTPUT VOLTAGE RELATIVE TO VOLTAGE ADJUST SETTING.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Unregulated DC present at (C1) in expected magnitude (15 to 30% higher than output voltage at nominal line voltage at no load).	1. Amplifier or sensing circuit defective.	1. Check by momentarily shorting base to collector of (Q101). If this restores DC output, check sensing voltage divider. See end of this Section for amplifier check.
	2. Rate sensing capacitor (C104) has excessive leakage.	2. Disconnect one terminal of capacitor. If this restores DC output, replace capacitor.
B. Unregulated DC present at C1, but almost same magnitude as low output voltage.	1. Defective Mag-amp control.	1.
	a. Mag-amp sensing defective. Check that base of Q103 is operated at approximately (within less than 50 mv) of base of Q102.	a. If bases are equal, check voltage at CR109 for +18 volts, and check values of R111, R105, R104 for faulty components.
	b. Faulty transistor Q102, Q103.	b. If base to base voltage is unbalanced by more than 50mv,

SYMPTOM	POSSIBLE CAUSE	REMEDY
		b. (continued) change the transistors.

4-6. HIGH OUTPUT VOLTAGE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output voltage adjust knob has little or no control over DC output.	1. External sensing circuit improperly connected. Internal sensing voltage divider or wiring open.	1. With power off, check continuity of sensing leads, internal sensing circuit from positive output terminals to amplifier input (20) and from negative output terminal to neutral bus of amplifier (21).
B. Output control effective. Driver base (Q101) negative with respect to negative output terminal.	1. a. Bleeder resistor (R2) open, or regulator transistors (Q1 thru Q3) I_{CO} drain open (R107).	1. a. Check by applying full load. If this restores normal operation, check for open resistor or connection.
	b. Defective amplifier.	b. See amplifier check at end of this Section.
	c. Defective amplifier power supply.	c. Check voltage across filter capacitor (C103), (C102) as shown on schematic diagram. If correct check resistors (R3, R110, R108) for open. If incorrect, check the capacitors, (C102, C103) diodes (CR101 thru (CR104) and secondary winding of transformer (T1).
C. Driver base (Q101) positive with respect to negative output terminal.	1. Defective driver and/or pass transistor.	1. Check for shorted transistors.

4-7. FAILURE TO REGULATE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation is 5% or more, line regulation 2% or more.	1. a. Defective amplifier.	1. a. See amplifier check at end of this Section.
	b. Defective amplifier power supply.	b. Check voltage values of filter capacitors (C103) (C102). If incorrect, check the capacitors, diodes (CR101 thru CR104), and main secondary winding of transformer (T1). Check (R110 and R108) for open.
	c. Open (R107)	c. Replace.
	d. Very low performance transistor in regulator or driver circuit.	d. Check for equal voltages across resistors in series with emitters of power transistors, to detect defective transistor. Check transistors in a transistor test set or by substitution.

4.8. POOR REGULATION.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Load regulation less than 5%, but not within specifications.	1. External sensing circuit incorrectly connected.	1. Check by operating unit with sensing terminals temporarily jumpered to the local output terminals. (Observe correct polarity).
	2. Low gain amplifier.	2. See amplifier check at rear of this Section.
	3. Low beta in driver or power transistor.	3. Check by substitution or in transistor tester. Beta of 20 or more is acceptable.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	4. Oscillating amplifier.	4. Check (C105) for proper value. See amplifier check at the rear of this Section.

4-9. EXCESSIVE RIPPLE.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Output regulation is within specifications.	1. a. Circuit not by-passed to ground.	1. a. One output terminal of the supply should be connected to chassis ground whenever practical, either directly or through a 0.1 mfd. capacitor of appropriate voltage rating.
	b. Filter capacitor (C1, C2) - (C102), or (C103) open or of low value.	b. Replace.
	c. Note: Ripple at (C1) should not exceed 5%.	c. Replace.
	d. Rate-sensing capacitor (C104) open or of low value.	d. Replace.
	e. Hum pickup in external sensing leads.	e. Check by operating unit with sensing terminals temporarily jumpered to local output terminals. Shield or twist external sensing leads.
	f. Low-gain amplifier.	f. See amplifier check at end of this section.
B. Output regulation poor.	1. a. Low beta in power transistor or driver transistor.	1. a. Check by substitution or in transistor test set. Beta of 20 or more is acceptable.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	b. Low gain amplifier.	b. See amplifier check at the end of this Section.
	c. Defective amplifier power supply.	c. Check diodes (CR101 thru CR104) for shorts, or open capacitors (C102), (C103) for open, low value, or high leakage. Check diodes (CR110) (CR109) and resistors (R108) and (R110).

4-10. INSTABILITY.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Random large excursions of output voltage.	1. Intermittent failure of component or intermittent short or open in circuit.	1. Check primary power circuit by temporarily connecting base of driver transistor (Q_1) to negative output terminal. If instability persists, check for intermittent breakdown in rectifiers (CR1 and CR2) or filter capacitors (C1 and C2). Check for intermittent opens or shorts in unregulated DC circuit. Check driver and power transistors in tester, or by substitution. Check for intermittent opens or shorts, or defective component from (C1) to output terminals. Look for intermittent open or short, or intermittently defective component in (1) amplifier, (2) amplifier power supply, or (3) sensing voltage divider and external sensing circuit.

SYMPTOM	POSSIBLE CAUSE	REMEDY
		1. (Continued) Check amplifier connector for poor contact. Check rate-sensing capacitor (C104). Check voltage across (CR109, CR-110 and CR111) for atability.
B. Gradual drift in one direction at any load, after 15-minute warm-up.	2. a. Defective amplifier.	2. a. See amplifier check at end of this section.
	b. Drifting zeners.	b. Check (CR109, CR110) and (CR111). Replace if faulty.
	c. Output adjust potentiometer (R5) unstable.	c. Replace.

4-11. INADEQUATE TRANSIENT RESPONSE.

NOTE: This condition should be checked by oscilloscope at the output terminals of the supply, with the sensing terminals temporarily jumpered to the corresponding output terminals. None of the load current should be permitted to flow through any portion of the oscilloscope leads or the sensing leads.

SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Regulation and ripple are within specification, and external sensing circuit is properly and firmly connected.	1. a. By-pass capacitor (C2) open, or very low in value.	1. a. Replace.
	b. Filter capacitor (C1) low in value.	b. Replace.
	Note: A brief transient during switching is normal. The measurement of transient response may be complicated by inductive transients of 1 to 50 microsecond duration due to lead inductance etc., but since these are	

SYMPTOM	POSSIBLE CAUSE	REMEDY
	Note: (continued) easily handled by means of local by-passing, they have no significance in determination of the transient response of the supply.	

4-12. OSCILLATION.

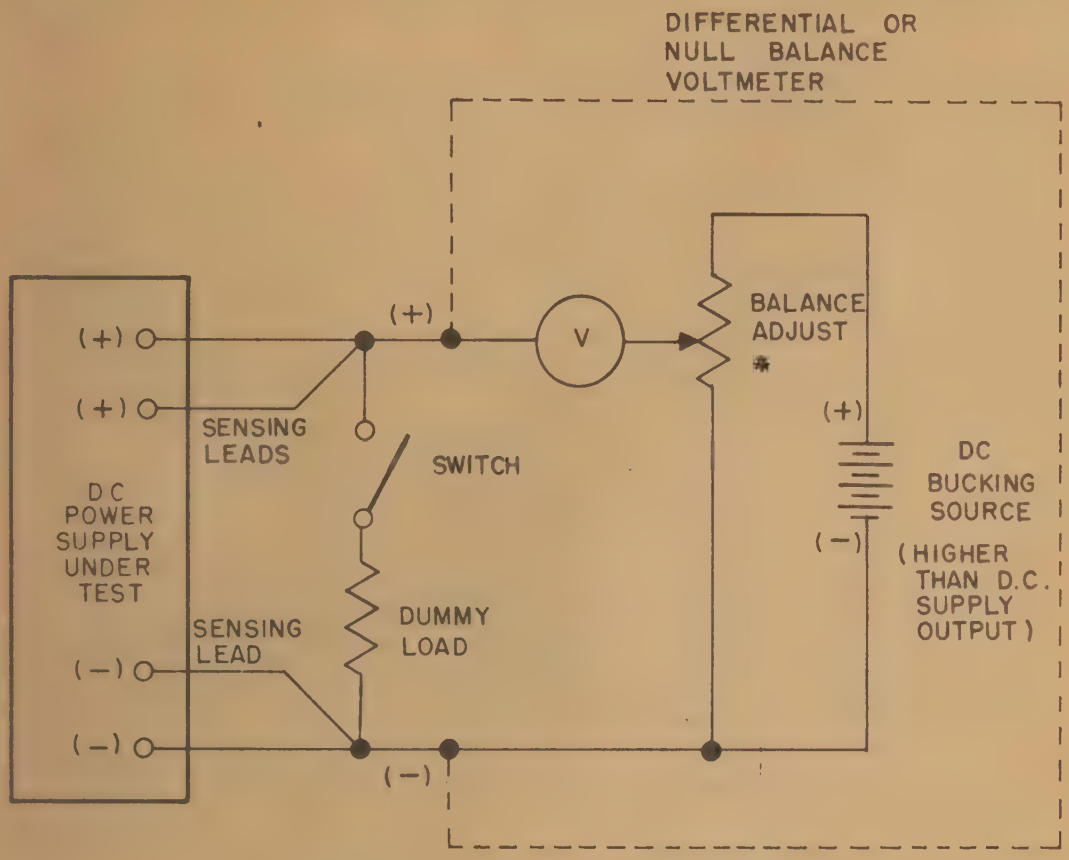
SYMPTOM	POSSIBLE CAUSE	REMEDY
A. Under constant load, output voltage varies at a cyclic rate (sawtooth or sine wave) of 200 cycles or more per second.	1. a. Defective diodes (CR109), (CR110), or resistors (R110) (R108).	1. a. Replace.
	b. By-pass capacitor (C2) is open or of low value.	b. Replace.
	c. Rate sensing capacitor (C104) or its circuit is open.	c. Replace.
	d. Suppressor capacitor (C105) in amplifier is open or of low value.	d. Replace.
B. Under constant load, output voltage varies in "sawtooth" manner at a frequency of 200 cycles or less.	2. a. Output capacitor (C2) is open.	2. a. Replace.
	b. Magnetic storage regulator is oscillating. Check (C101) and (R106) for proper value. (Check voltage across (C1) for sawtooth wave) higher than normal 5% ripple.)	b. Replace faulty components.
	c. Rate sensing capacitor (C104) is open, or of low value.	c. Replace.

SYMPTOM	POSSIBLE CAUSE	REMEDY
	d. Excessive capacitance in external load circuit.	d. If load contains capacitance equal to or greater than output capacitor (C2), special precautions are necessary. Check with NJE Corp. engineering department.
	e. Excessive amplifier gain.	e. If the beta (current gain) of one or more amplifier transistors is 150% or more of the manufacturer's bogie value, the increased gain which results (particularly at high ambient temperature) could result in this type of oscillation. Replacement of the transistor is required.

4-13. REGULATION CHECK. Because of the inherently slight regulation exhibited by this power supply, it is impracticable to make a regulation check by observing a voltage measurement across the output terminals of the supply as the line or load is varied.

4-14. To accurately check the regulation, it is necessary to use an external source of DC voltage of approximately the same value as the power supply output, connected as shown in Figure 3. This DC bucking voltage can be either an electronic unit, null balance differential voltmeter, or a group of batteries connected in series, furnishing a DC potential larger than the output voltage of the power supply under test. The voltmeter should have a full-scale range of 0 to 5 or 10 volts (5-0-5 with center zero, if available), since it will be used to measure only the difference between two almost equal voltages. The balance adjustment is used to bring the meter needle to approximately midscale before testing, so that the deviation above or below the normal output of the supply under test can be observed.

4-15. The dummy load is selected to draw full load current at the nominal output voltage of the supply. The difference between the voltmeter readings with the switch open and closed (allowing the needle to come to rest before reading), gives the static load regulation in volts.



* RUN AS LITTLE CURRENT AS POSSIBLE THRU DIVIDER SO THAT BATTERY VOLTAGE DOES NOT DECAY

PRECISE REGULATION CHECK

FIGURE 3

4-16. Dynamic regulation is measured by substituting a calibrated oscilloscope for the voltmeter, and measuring the maximum deflection as a dummy load of appropriate value is switched in and out of the circuit.

4-17. FEEDBACK AMPLIFIER CHECK. There are several methods which can be used in checking the performance and condition of the feedback amplifier.

Except for individually removing the transistors for a check by means of a transistor test set, and making continuity and resistance tests on the circuit and components, all methods require the amplifier to be energized with the proper potentials under the conditions found in the power supply for normal operation. For this reason, it is simplest to test the amplifier in position in the supply, first making certain that its DC power supply (transformer T1), rectifiers (diodes CR101 thru CR104), capacitors (C102 and C103), diodes (CR109 and CR110) and resistors (R110 and R108) are functioning properly. This can be quickly ascertained by checking the circuit voltages as indicated on the schematic diagram. Once this is done, the procedures given below can be used to check out the amplifier itself.

a. Voltage Check. The simplest and most rapid direct check of the amplifier is made by connecting a temporary jumper from the base of transistor (Q107) to the base of transistor (Q108), thereby balancing the amplifier input stage, and checking for balanced voltages on the two amplifier stage collectors. Any obvious discrepancy will indicate a defective stage, and simple analysis will pinpoint the defective connection or component. Verification is then made by testing the component itself or repairing the connection.

b. Signal Tracing Check. Since there is an inherent amount of ripple at the input to the amplifier, this ripple signal can be used as a test signal for observing the amplifier performance with the aid of a test oscilloscope. (Ignore any spikes in the waveform. Use only the basic ripple signal when making amplitude calculations). In the event that the ripple is too small for practical use, a small 60-cycle sine wave voltage of convenient amplitude (less than 1/4-volt) can be injected into the amplifier, applying it across amplifier terminals (21) and (20) on printed circuit board for convenience. Measurement of the ripple at the input to the amplifier, and at the output of each successive amplifier stage will provide an effective check of amplifier performance. The ripple amplitude measured across the bases (or input) of the second stage transistors (Q105 and Q106) should be 20 to 40 times the amplitude at the input to the first stage. The ripple at the base of the next stage, transistor (Q104) should be 15 to 30 times the ripple at the input to the previous stage. The ripple at the output terminal (15) of the amplifier should be roughly the same as the input to transistor (Q104). Radical departure from this set of conditions will point up a defective component or connection, which can then be isolated by inspection and individual test. Be sure not to over drive the amplifier stages as it will cause misleading results.

c. Stability Check. A detailed check for improper drift and intermittent failure can be made by utilizing a test rig similar to that shown for precise regulation check in Figure 3. The voltage across the

zener diode reference source (CR111) is "bucked out", and monitored by a 0 to 1-volt (or smaller scale, if available) high impedance DC voltmeter (null balance voltmeter). Drift or random instability will be readily visible in this test. Output voltages of the successive amplifier stages and regulating diodes (CR109) and (CR110) can then be monitored in the same manner. When checking a given amplifier stage by this method, the output of the previous stage should be shorted, to prevent external voltage variations from reaching the stage under test. When installing a new transistor in place of one shown to be defective, the stability check should be repeated, to make certain that the trouble has been eliminated.

MANUFACTURERS REPRESENTATIVES

Waltham, Mass.
Burlingame Associates, Ltd.
974 Main St., Waltham, Mass.
TWinbrook 4-1955

Syracuse, N. Y.
Burlingame Associates, Ltd.
514 University Bldg, Syracuse, N. Y.
GRanite 4-7409

New York City Area
Burlingame Associates, Ltd.
510 South Fulton Ave., Mt. Vernon, N. Y.
MOunt Vernon 4-7530

Upper Darby, Pa.
Burlingame Associates, Ltd.
222 Long Lane, Upper Darby, Pa.
SHerwood 7-9080

Washington, D.C.
Burlingame Associates, Ltd.
8218 Wisconsin Ave., N.W., Washington 14, D.C.
OLiver 4-6400

Alexandria, Va.
W. A. Brown & Associates, Inc.
3610 Mt. Vernon Ave., P.O. Box 5007
George Washington Sub Station
Alexandria, Virginia
TEmple 6-1800

Huntsville, Ala.
W. A. Brown & Associates, Inc.
3405 Lookout Drive, S.E., Huntsville, Ala.
JEfferson 6-8393

Indian River City, Fla.
W. A. Brown & Associates, Inc.
P.O. Box 286, 201 Capron Rd.,
Indian River City, Florida
AMherst 7-0411

Orlando, Fla.
W. A. Brown & Associates, Inc.
711 Magnolia Ave., Orlando, Florida
GArden 5-5682

Winston-Salem, N.C.
W. A. Brown & Assoc., Ltd.
1707 Princeton St., S.W., Winston-Salem, N.C.
PArk 5-5384

Detroit, Mich.
Ridgway Associates, Inc.
1204 No. Woodward Ave., Royal Oak, Mich.
LIncoln 6-3312

Cleveland, Ohio
Ridgway Associates, Inc.
5915 Schaaf Road, Cleveland 31, Ohio
LAfayette 4-1421

Dayton, Ohio
Ridgway Associates, Inc.
3130 Far Hills Avenue, Dayton 29, Ohio
EXminster 3-2167

Chicago, Ill.
Ridgway Associates, Inc.
6100 W. North Ave., Chicago 39, Ill.
TUxedo 9-5715

Indianapolis, Ind.
Ridgway Associates, Inc.
1224 N. Capitol, Indianapolis 2, Indiana
MElrose 5-2401

Kansas City, Mo.
Lee Mark Associates
4021 W. 86th St., Kansas City 15, Mo.
NIagara 2-3313

St. Louis, Mo.
Lee Mark Associates
1500 Big Bend Blvd., St. Louis 17, Missouri
MIssion 7-1470

San Marino, Calif.
G. S. Marshall Company
2065 Huntington Drive, San Marino, California
MUrray 1-6781

San Diego, Calif.
G. S. Marshall Company
3525 Fifth Ave., San Diego, California
CYpress 8-8234 CYpress 8-8235

San Francisco, Calif.
G. S. Marshall Company
2015 South El Camino Real
Redwood City, California
EMerson 6-8214

Tucson, Arizona
G. S. Marshall Company
2030 East Broadway, Tucson, Arizona
MAine 2-4719

Centerville, Utah
Barnhill Associates
207 North 4th East, Centerville, Utah
ELgin 5-5101

Albuquerque, N.M.
Barnhill Associates
8310 Cutler Avenue, Albuquerque, New Mexico
AXtel 9-7997

Denver, Colo.
Barnhill Associates
1170 South Sheridan Blvd., Denver, Colorado
WEst 5-4645

Seattle, Washington
Burt C. Porter Company
1209 Poplar Place, Seattle, Washington
EAst 3-8330

Montreal, Canada
Radionics, Ltd.
8230 Mayrand St., Montreal, Canada
REgent 9-5517

OUR WARRANTY: N J E Corp. warrants each power supply manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replacing any defective parts thereof, except tubes, semi-conductors and fuses. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and which upon our examination is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started. Written permission must be obtained from the factory, before a supply may be returned for examination.

NJE CORPORATION
Electronic Development & Manufacturing
Kenilworth, New Jersey • BRidge 2-6000
TELEFAX: FFP • TWX: CRANFORD 51

NJE CORPORATION

Electronic Development & Manufacturing

Kenilworth, New Jersey • BRidge 2-6000

TELEFAX: FFP • TWX: CRANFORD 51

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